Flow Over Difficult Bathymetry: Processes and Parameterizations

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LONG-TERM GOALS

To understand the physics of flows generated by currents passing over small topographic features, to quantify, and parameterize if possible, the mixing these flows produce; and to parameterize the effects of form drag on topographic roughness at scales too small to be resolved by numerical models of ocean circulation.

OBJECTIVES

To synthesize emerging measurements and numerical simulations of flow and mixing over rough topography to assess their global importance.

To understand the physics controlling exchanges of momentum, heat, and salt between boundary layers over continental slopes and the ocean's interior.

To use laboratory and numerical results to design experiments to illuminate crucial aspects of flow and mixing over rough topography.

To make observations of form drag on coastal currents, which may be compared directly with calculations of form drag from realistic numerical simulations.

APPROACH

As described in our companion report, with an additional grant from ONR we developed a second generation of our depth-cycling towed body used to study flows close to rough topography. Called SWIMS 2, it has upward and downward 300 kHz ADCPs. During September 2002 we will use it during the Nearfield phase of the Hawaii Ocean Mixing Experiment (HOME) to examine flow structures over the Kaena Point ridge. Earlier this year we operated it in the Hood Canal to study flows over the South Point sill, which is off the Bangor submarine base.

Report Documentation Page

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14. ABSTRACT
To understand the physics of flows generated by currents passing over small topographic features, to quantify, and parameterize if possible, the mixing these flows produce; and to parameterize the effects of form drag on topographic roughness at scales too small to be resolved by numerical models of ocean circulation.

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WORK COMPLETED

Analysis of the latitude dependence of mixing produced by breaking internal waves was completed and submitted for publication. Matthew Alford also completed the analysis of internal wave shear observed with our Modular Microstructure Profilers (MMPs). This is the first time these shears have been measured with a loosely tethered profiler and expands the range of observational tools available for studying shear and mixing in shallow water.

RESULTS

One of our projects has been to test parameterizations for mixing rates in the open ocean. This year we finished compiling our observations from diverse latitudes, and Figure 1 summarizes the residual variability after observed dissipation rates are normalized for shear, strain, and stratification. This variability falls within the octave about the latitude scaling predicted by Henyey et al. (1986), a rather unexpected result in view of the assumptions of linearity made in the model. This confirms that the wave-wave interactions driving energy toward small scales and breaking indeed slow when approaching the equator.

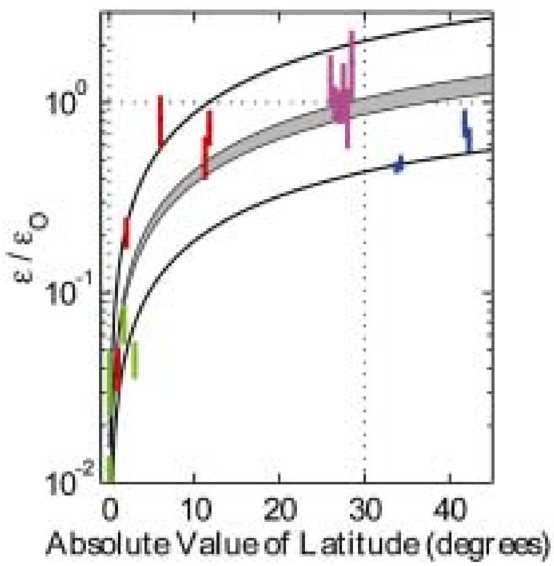

Fig. 1 Turbulent dissipation rates normalized by predicted rates considering all factors except latitude (Gregg et al, submitted). Grey shading shows the predicted latitude dependence for the range of stratifications observed. The two solid lines are twice and half the prediction.

Washington Sea Grant funded us to collect observations of flow interactions over South Point sill in the Hood Canal using SWIMS2. We are analyzing the data on this project. Combining data from this year and last reveals a complicated structure that appears to result from the nature of the sill, which falls off to the south in a narrow steep valley on the west side of the canal and slopes gently downward on the east side of the channel. This produces a complicated pattern of lee waves that have their largest amplitude on the eastern side (Figs. 2 and 3). Having demonstrated the nature of the flow, we are analyzing the data to see where they fit in the scheme of hydraulically-controlled flows and to understand what effects they have on exchanges of water and tracers along the canal.

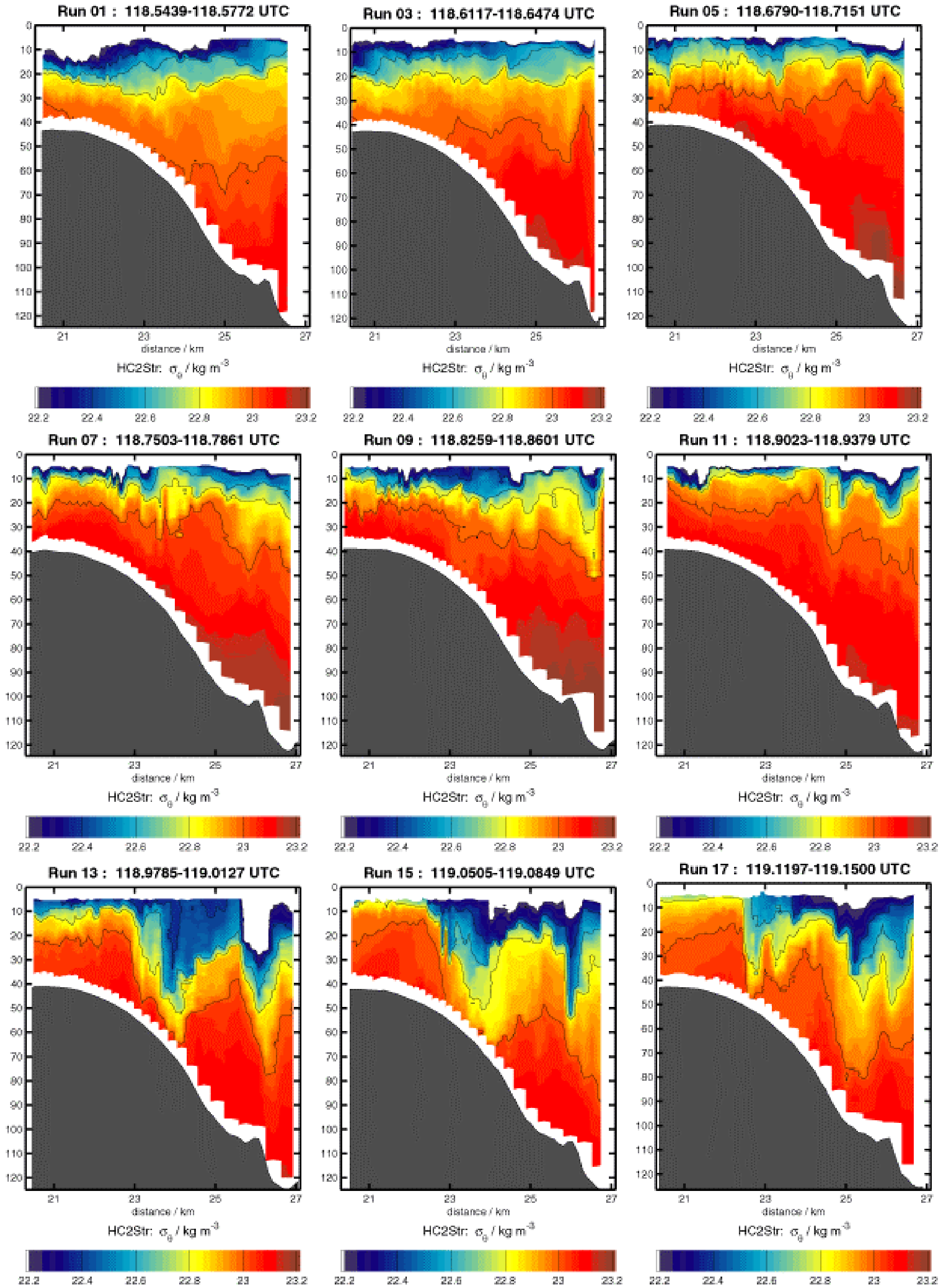

Fig. 2 Evolution of density over the eastern part of South Point sill in the Hood Canal. Peak ebb flow was during run 6. Slack water fell between runs 9 and 10. Peak flood was during run 12, and slack was during run 17. The strong lee waves developed during flood and persisted through the following slack water.

Fig. 3 Surface slick over one of the strong lee waves in the Hood Canal, looking east.

Another of our projects was to make observations of form drag at a sharp headland, Three Tree Point, WA, where tidal currents force the formation of both horizontal eddies, and internal lee waves. This observational program is also supported by NSF. Form drag is calculated as a spatial integral of bottom pressure times slope angle, across the Point. The barotropic form drag on a number of sections across the Point was calculated using ~90 Lagrangian drifter tracks, formed as a composite of data from 9 days in June 2002, aligned by tidal phase. The drifters, drogued at 20 m, are little affected by wind (they are too deep) or baroclinic forces (they are too shallow – the full water column depth is 230 m) and so respond mainly to the pressure force of the surface height. Using the Lagrangian acceleration from the drifters has allowed a graduate student, Ryan McCabe, to map the surface height field. This is mainly due to a tidal headland eddy in the lee of the Point, with 1 km horizontal scale and vorticity up to 10 times the Coriolis frequency. This novel method allows us to resolve surface height changes of just a few centimeters, and to make form drag calculations on a number of sections across the Point (Fig. 1). The baroclinic form drag on a section across the Point was calculated for nine separate high-resolution CTD/microstructure sections, made in March 2001 by Jim Moum's group (OSU) using his Chameleon profiler, and analyzed by postdoc Kate Edwards. The baroclinic form drag increased with tidal current, as shown in Figure 4.   The normalized frictional drag was also calculated from the Chameleon sections, where dissipation data allowed direct calculation of the bottom frictional stress on each drop. The overall results show that form drag vastly dominates the frictional drag on this piece of rough topography, and that the baroclinic and barotropic contributions to form drag are similar in magnitude. These results are consistent with those from realistic numerical simulations, and underscore the importance of form drag to the conversion of energy from tidal currents to both eddies and internal wave mixing.

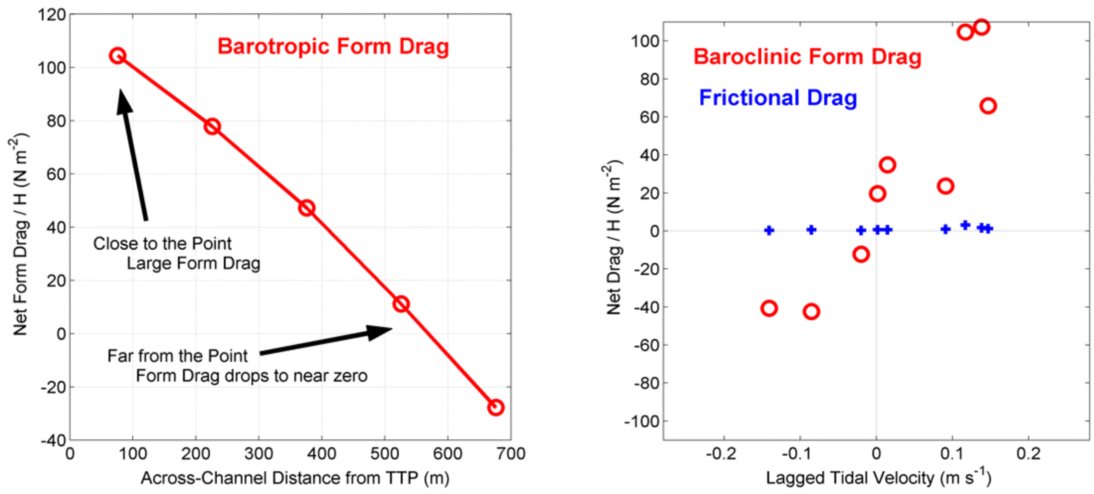

Figure 4. Left: barotropic form drag across Three Tree Point, at maximum flood current. Right: baroclinic form drag, and frictional drag across the Point, calculated from nine high-resolution CTD sections, at a variety of tidal phases. All drags are normalized by ridge height.

IMPACT/APPLICATIONS

The latitude scaling of mixing produced in the open ocean by breaking internal waves will allow large-scale modelers to develop more realistic parameterizations than the constant values they now use.

The observations in the Hood Canal further our understanding of sill flows in general, important for understanding flows through many straits, and in particular reveal the flow regime offshore of the submarine base.

The observations at Three Tree Point will contribute to the parameterization of pressure drag effects on unresolved topography. This has proven to be very important to accurate numerical weather simulation. In the coastal ocean the additional effects of sloping sidewalls and the nearby free surface makes direct application of the atmospheric results difficult, so different parameterizations are necessary.

TRANSITIONS

Unknown.

RELATED PROJECTS

Data collection in the Hood Canal is funded by Washington Sea Grant. NSF is funding most of our work during HOME, but this project and other ONR funding allows us to use SWIMS2 and to link the results to our broader body of work.

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